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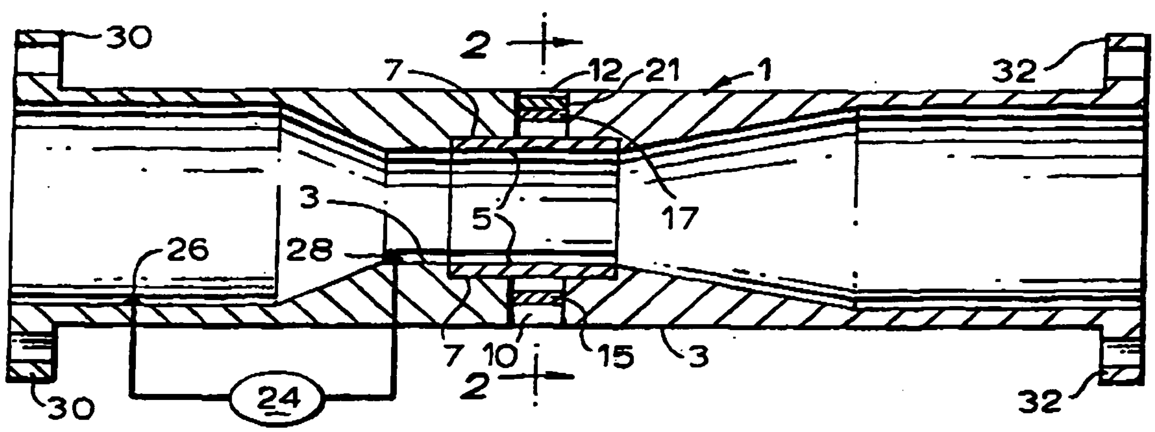

(57) Abstract

An apparatus for measuring a composition of a fluid flowing through a flowlines is provided, the apparatus comprising a conduit (1) suitable to be connected to the flowline so that a stream of the fluid flows through the conduit, a radioactive source (15) arranged in a manner that radiation from the source passes through the stream of fluid and through a wall of the conduit, a detector (17) for detecting radiation passing through said stream and through said wall, and means to generate a signal representative of the radiation detected by the detector. In one aspect of the invention the wall of the conduit (1) comprises a fibre reinforced resin. In another aspect of the invention the detector (17) comprises a solid state detector cooled by a Peltier element (21).

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FLUID COMPOSITION METER

The invention relates to an apparatus for measuring a composition of a fluid flowing through a flowline. When a multi-component fluid is transported through a flowline to a processing facility, it is generally required to measure the composition of the fluid either at a location along the flowline or at the upstream end thereof. In the oil and gas industry, wellbore fluids can be transported from an onshore or offshore wellhead through a flowline to a processing facility where the different components of the fluid are separated from each other. The wellbore fluids can include oil, gas and water in fractions which can vary in time and can be different for different wells producing from the same subsurface reservoir. Measurement of fluid composition directly at the wellheads or further downstream where streams from different wells are joined enables specific reservoir characteristics to be updated during the producing lifetime of the reservoir, and allows timely corrective measures to be taken if necessary.

European patent No. 269 432 discloses an apparatus for measuring a composition of a fluid flowing through a flowline, comprising a conduit suitable to be connected to the flowline in a manner that a stream of said fluid flows through the conduit, a radioactive source arranged so that radiation from the source passes through a wall of the conduit and through the stream of fluid, a radiation detector arranged so as to detect said radiation passing through the wall of the conduit and through the stream of fluid, and means to generate a signal representative of said radiation detected by the detector. The amount of radiation passing through the stream of fluid and which is detected by the detector provides an indication of the composition of the fluid. The wall of the conduit through which radiation passes forms a radiation window made of beryllium, which wall is surrounded by a tubular guard provided with diametrically opposed holes for passage of the radiation. A drawback

of the known device is that toxic beryllium oxide will form on the surface of the beryllium wall. Furthermore, for high pressure applications a relatively thick beryllium wall is required, resulting in a significant attenuation of radiation in the beryllium wall and a corresponding reduction of accuracy of the composition measurement.

It is an object of the present invention to provide an apparatus for measuring a fluid composition of a stream of multi-component fluid, which overcomes the drawbacks of the prior art apparatus.

It is another object of the invention to provide an apparatus for measuring a fluid composition of a stream of multi-component fluid, which apparatus is compact and provides accurate measurements.

In accordance with one aspect of the invention the apparatus for measuring a composition of a stream of fluid flowing through a flowline is characterized in that the wall of the conduit comprises a fibre reinforced resin. It has been found that the wall of fibre reinforced resin forms an adequate radiation window with low radiation absorption, while such a wall allows relatively high internal pressures to be applied. Furthermore, in the absence of beryllium there is no danger that beryllium oxide will form, and future problems of disposing beryllium are eliminated.

Absorption of radiation in the conduit wall is particularly low when the wall is reinforced with carbon fibres. In view thereof it is preferred that the wall comprises a relatively high percentage of carbon fibres, for example between 50-70% wt carbon fibres.

A suitable matrix material to be applied for the wall forms a polyether resin, such as an epoxy resin.

In accordance with another aspect of the invention the apparatus for measuring a composition of a stream of fluid flowing through a flowline is characterized in that the detector comprises a solid state detector. It is to be understood that in the context of the present invention the solid state detector refers to a semiconductor diode detector, for example as described in

publication ISBN 0-471-49545-x entitled "Radiation detection and measurement", chapter 11. Such a detector is compact and has a high resolution in the energy range between 15-100 keV which is suitable for the measurement. The resolution and efficiency of the semiconductor diode detector can be increased by providing the detector with cooling means which maintain the temperature of the detector between 0-15 °C, or preferably between 5-10 °C.

A suitable cooling means forms a Peltier element since such element is compact, whereby the compactness of the apparatus is even enhanced when the detector is directly attached to the Peltier element.

The composition of the fluid flowing through the flowline is determined from the signal representing the radiation detected by the detector according to the following method:
The absorption of gamma rays in matter is described by the following equation:

$$I(e) = I_o(e).\exp(-\mu(e).h,$$

where

$I_o(e)$ = initial intensity of the gamma rays at energy e;
$I(e)$ = intensity of the gamma rays after absorption at energy e;
$\mu(e)$ = linear absorption coefficient at energy e;
h = thickness of material.

Given an oil/water/gas mixture in a pipe of internal diameter d and wall thickness t, the following equations can be derived for two energy levels e1 and e2:

$$I(e1) = I_o(e1).\exp(-\mu_{mix}(e1).d).\exp(-\mu_{pipe}(e1).2t)$$

and

$$I(e2) = I_o(e2).\exp(-\mu_{mix}(e2).d).\exp(-\mu_{pipe}(e2).2t),$$

where

$$\mu_{mix}(e1) = \mu_{oil}(e1).\alpha_{oil} + \mu_{water}(e1).\alpha_{water} + \mu_{gas}(e1).\alpha_{gas}$$

and

$$\mu_{mix}(e2) = \mu_{oil}(e2).\alpha_{oil} + \mu_{water}(e2).\alpha_{water} + \mu_{gas}(e2).\alpha_{gas}$$

The symbol α refers to the volume fraction of the subscripted phase; the sum of all the three fractions should be equal to 1:

$$\alpha_{oil} + \alpha_{water} + \alpha_{gas} = 1$$

if the absorption coefficients for oil, water and gas are measured in separate calibration procedure, then, by measuring the radiation absorption through a pipeline filled with oil, water and gas, at two gamma-ray energy levels e1 and e2 the three fractions α_{oil}, α_{water} and α_{gas} can be determined using the above equations.

In general, the efficiency of a solid state detector decreases with increasing radiation energy level. If for example an Americium (Am-241) radiation source is used which radiates at a low energy level of 18 KeV and at a high energy level of 60 KeV, the detector efficiency at the low energy radiation level is about 50-60 %, while the detector efficiency at the high energy radiation level is about 5 %. One solution to this problem could be to select a solid state detector having a relatively large detecting surface, so that the count-rate of the detector at the higher energy levels is increased. Another, preferred, solution to improve the efficiency of the detector is to provide the detector with at least two radiation detecting surfaces, whereby a filter is located between the radiation source and a first of said detecting surfaces, which filter substantially prevents the low energy radiation to pass therethrough, and which filter substantially allows the high energy level radiation to pass therethrough. Thereby it is achieved that the low energy level portion of the radiation passing through the fluid mixture and the wall of the conduit is substantially detected by a second of said two detecting surfaces. Furthermore, the high energy level portion of the radiation which passes through the fluid mixture and the wall of the conduit is substantially detected by said first detecting surface at an increased efficiency since by the arrangement of the filter the count-rate for the high energy level portion is significantly increased. Preferably the filter comprises Copper.

The invention will now be described by way of example in more detail with reference to the drawings in which:

Fig. 1 shows schematically a longitudinal cross-section of the apparatus according to the invention;

Fig. 2 shows cross-section 2-2 of the apparatus of Fig. 1;

The apparatus of Figs. 1 and 2 includes a steel conduit 1 having a central part 3 of reduced internal diameter. A carbon fibre reinforced epoxy (CFRE) cylinder 5 is located in a recess 7 provided at the inside of the central part 3 of the conduit 1. The wall of the central part 3 of the conduit 1 is provided with four openings 10, 11, 12, 13, whereby openings 11, 12, 13 are arranged opposite opening 10 and at spaced intervals along the circumference of the conduit 1. Each opening 10, 11, 12, 13 extends from the outer surface of the conduit 1 to the outer surface of the CFRE cylinder 5.

An X-ray or gamma-ray radiation source 15 is located in opening 10 which forms a collimator for the source 15. Three solid state detectors 16, 17, 18 are located in openings 11, 12, 13 respectively, which openings 11, 12, 13 form respective collimators for the detectors 16, 17, 18 so that the latter can detect radiation from the source 15. The detectors 16, 17, 18 are attached to respective Peltier elements 20, 21, 22 which serve to maintain the temperature of the detectors 16, 17, 18 between 5-10 °C. An electronic processor (not shown) is linked to the detectors 16, 17, 18 to receive and process signals representing the radiation detected by the detectors 16, 17, 18.

The radioactive source 15 is selected such that suitable energy levels e1 and e2 are emitted so that α_{oil}, α_{water} and α_{gas} can be solved using the above equations.

A differential pressure meter 24 is connected to a pressure tap 26 located at the inner surface of the conduit 1 adjacent the central part 3 thereof, and to a pressure tap 28 located at the inner surface of the central part 3 of the conduit 1.
The conduit 1 is at both ends provided with flanges 30, 32 to connect the conduit 1 to a flowline (not shown) for transporting fluid containing oil, water and gas produced from a wellbore in an earth formation.

During normal operation of the apparatus shown in Figs. 1 and 2, the conduit 1 is connected to the flowline and a stream of fluid containing oil, water and gas produced from the wellbore flows through the conduit 1. X-ray or gamma-ray radiation emitted by radiation source 15 passes through the wall of the carbon fibre reinforced cylinder 5 and through the stream of fluid towards the detectors 16, 17, 18, whereby the radiation is partly absorbed by the wall of the CFRE cylinder 5 and by the stream of fluid. Thus, the radiation emitted by the source 15 is attenuated by the wall of the CFRE cylinder 15 and by the stream of fluid. The attenuated radiation is detected by the detectors 16, 17, 18 and signals representing the attenuated radiation are received by the electronic processor which determines the composition of the fluid using the above equations. Furthermore, the differential pressure meter 24 provides signals representing the flow rate of the fluid mixture, so that the flowrates of the individual fluid components can be calculated.

Application of several detectors at circumferentially spaced locations around the conduit has the advantage, compared to applying only one detector, that the count-rate is thereby increased and that the homogeneity of the fluid can be checked by comparing the fluid composition as determined from the individual detectors. In the embodiment shown in Figs. 1 and 2 three detectors are applied, however less or more than three detectors can be applied in the apparatus according to the invention depending on the characteristics of the application.

A suitable material for constructing a CFRE cylinder for use in the apparatus described with reference to Figs. 1 and 2 comprises Araldit LY556 resin with HY917 hardener and DY070 hardening accelerator manufactured by Ciba Geigy, and Tenax IM-400-12000 carbon fibres manufactured by AKZO. A CFRE cylinder was constructed from this material with an internal diameter of 43 mm and a wall-thickness of 2mm, and was positioned within a steel conduit provided with one 16 mm diam opening and three 8 mm diam openings for locating the radiation source and the three detectors respectively.

A pressure test revealed that the CFRE cylinder could withstand an internal pressure of 120 MPa.

To reduce attenuation of the radiation in the wall of the conduit, in an alternative embodiment of the apparatus according to the invention at least one of the source and the detector is arranged within the conduit.

In such embodiment, it is preferred that the source is arranged within the conduit and the detector is arranged outside the conduit. Thus the radiation passes through the wall of the conduit only once. Suitably the source is surrounded by a sleeve located within the conduit, which sleeve preferably is arranged concentrically within the conduit.

CLAIMS

1. An apparatus for measuring a composition of a fluid flowing through a flowline, comprising a conduit suitable to be connected to the flowline in a manner that a stream of said fluid flows through the conduit, a radioactive source arranged so that radiation from the source passes through a wall of the conduit and through the stream of fluid, a radiation detector arranged so as to detect said radiation passing through the wall of the conduit and through the stream of fluid, and means to generate a signal representative of said radiation detected by the detector, wherein the wall of the conduit comprises a fibre reinforced resin.

2. The apparatus of claim 1, wherein the wall of the conduit comprises a carbon fibre reinforced resin.

3. The apparatus of claim 1 or 2, wherein said resin comprises a polyether resin.

4. The apparatus of claim 3, wherein said polyether resin comprises an epoxy resin.

5. The apparatus of any one of claims 1-4, wherein the detector comprises a solid state detector.

6. An apparatus for measuring a composition of a fluid flowing through a flowline, comprising a conduit suitable to be connected to the flowline in a manner that a stream of said fluid flows through the conduit, a radioactive source arranged so that radiation from the source passes through a wall of the conduit and through the stream of fluid, a radiation detector arranged so as to detect said radiation passing through the wall of the conduit and through the stream of fluid, and means to generate a signal representative of said radiation detected by the detector, wherein the detector comprises a solid state detector.

7. The apparatus of claim 5 or 6, wherein the solid state detector is provided with cooling means so as to maintain the temperature of the detector between 0-15 °C.

8. The apparatus of claim 5 or 6, wherein the solid state detector is provided with cooling means so as to maintain the temperature of the detector between 5-10 °C.

9. The apparatus of claim 7 or 8, wherein the cooling means is in the form of a Peltier element.

10. The apparatus of claim 9, wherein the detector is directly attached to the Peltier element.

11. The apparatus of any one of claims 1-10, wherein said conduit has along a part of its length a reduced diameter, and the apparatus further comprises means for measuring a differential pressure in the stream of fluid flowing through the part of reduced diameter.

12. The apparatus of any of claims 1-11, wherein at least one of the source and the detector is arranged within the conduit.

13. The apparatus of claim 12, wherein the source is arranged within the conduit and the detector is arranged outside the conduit.

14. The apparatus of any one of claims 1-13, wherein a plurality of detectors are arranged at circumferentially spaced locations around the conduit.

15. The apparatus of any of claims 5-14, wherein the solid state detector is provided with at least two radiation detecting surfaces, whereby a filter is located between the radiation source and a first of said detecting surfaces, which filter substantially prevents the low energy radiation to pass therethrough, and which filter substantially allows the high energy radiation to pass therethrough.

16 The apparatus of claim 15, wherein the filter comprises Copper.

17. The apparatus substantially as described hereinbefore with reference to the drawings.

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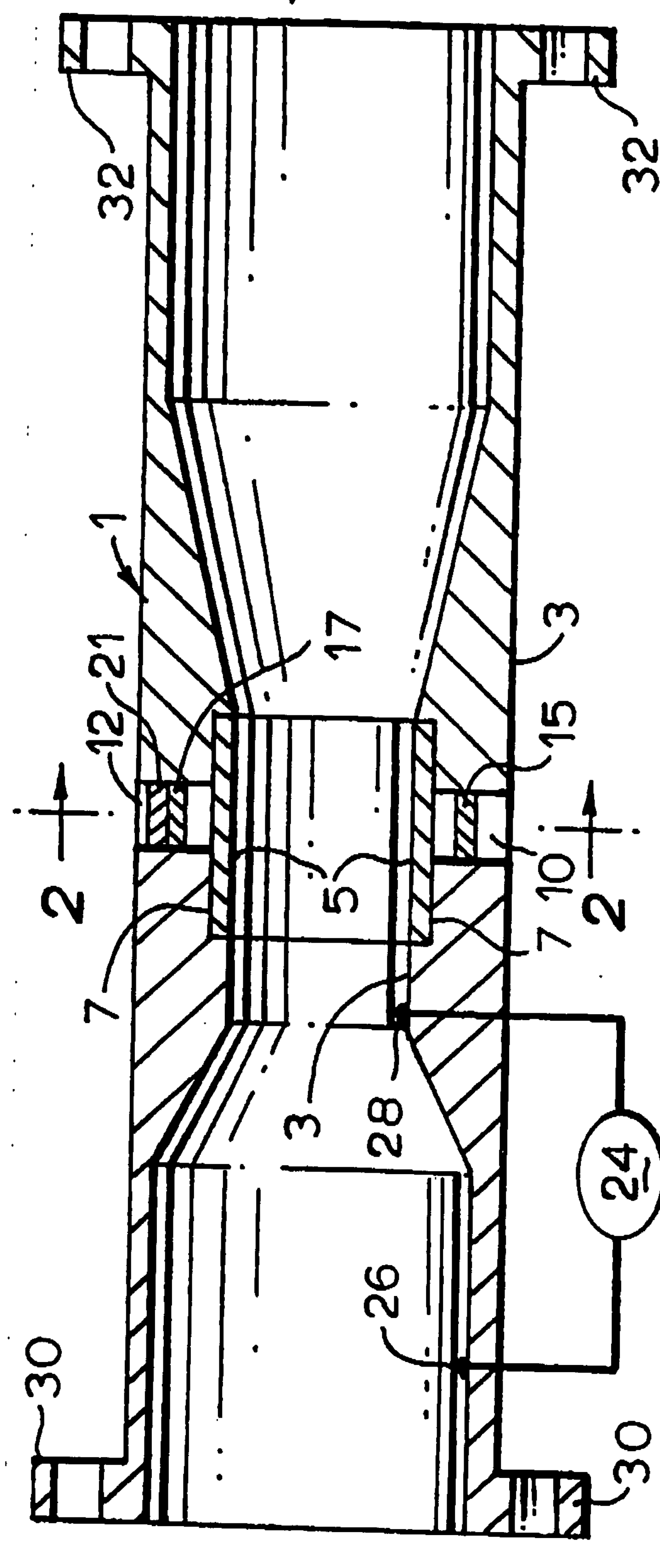
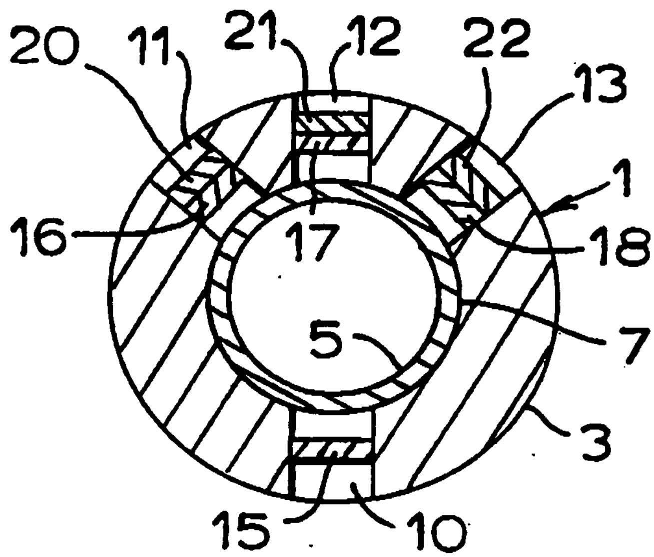


FIG.1

FIG. 2



INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 94/01320

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 G01N23/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 269 432 (PETRO-CANADA INC.) 1 June 1988 cited in the application see page 2, line 8 - line 15; figure 2	1,17
Y		6-14
A,P	WO,A,93 10439 (FRAMO DEVELOPMENTS LTD.) 27 May 1993 see abstract	1-4,6,17
Y	INTERNATIONAL JOURNAL OF APPLIED RADIATION AND ISOTOPES, vol.34, no.1, January 1983, OXFORD GB pages 309 - 331 J. S. WATT see page 329, paragraph 6.1	6-14

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[X] Further documents are listed in the continuation of box C.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	EP,A,0 236 623 (PETRO-CANADA INC.) 16 September 1987 see abstract; figures 1,2 ---	11-13
Y	EP,A,0 187 460 (U.K.A.E.A.) 16 July 1986 see page 5, line 6 - line 9; figure 5 ---	14
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 94/01320

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